

# Cluster Luttinger liquids in one-dimensional strongly correlated fermions interacting via a soft-shoulder potential

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# Model definition and motivations


## Hamiltonian

$$H = -t \sum_j [\hat{c}_j^\dagger \hat{c}_{j+1} + h.c.] + U_1 \sum_j \hat{n}_j \hat{n}_{j+1} + U_2 \sum_j \hat{n}_j \hat{n}_{j+2}$$

- spinless fermions on 1D lattice: hopping + density-density interactions
- $U_1 \in \mathbb{R}, U_2 \geq 0$
- extended interaction range

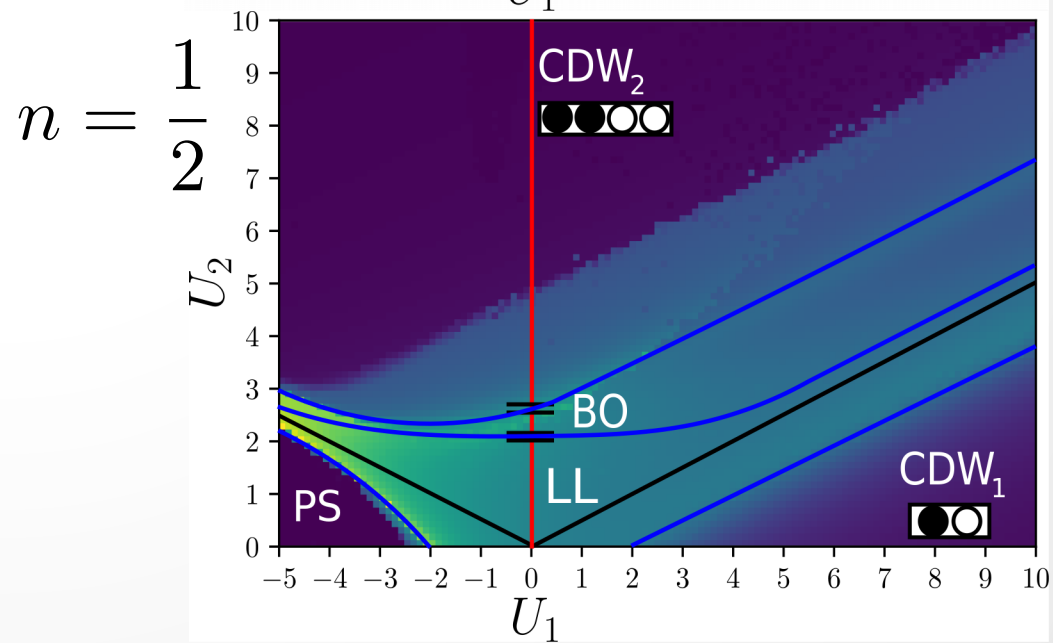
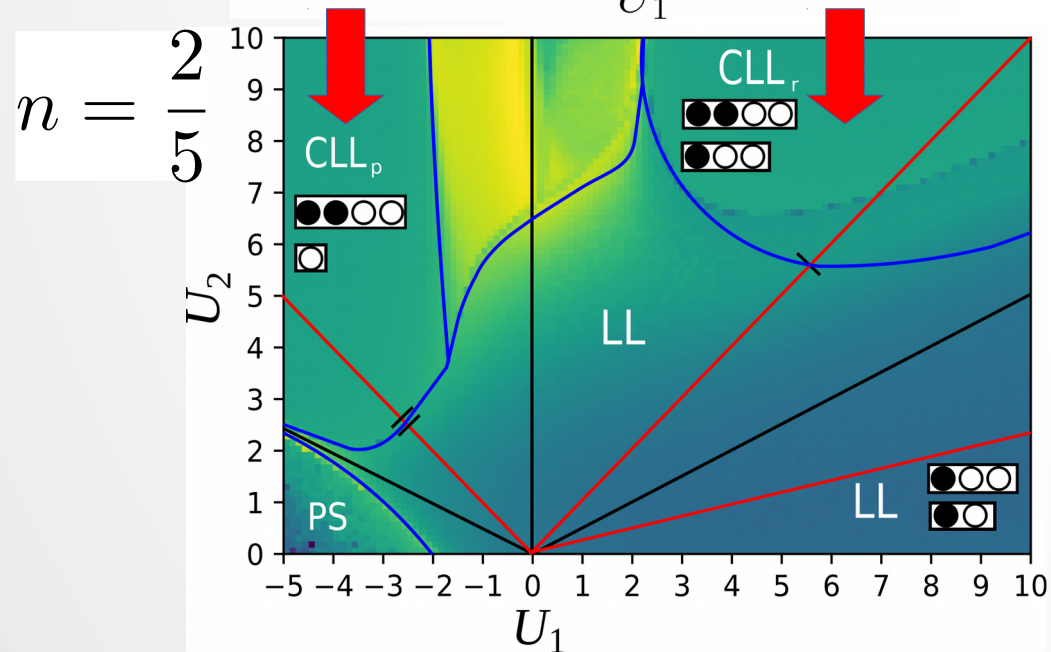
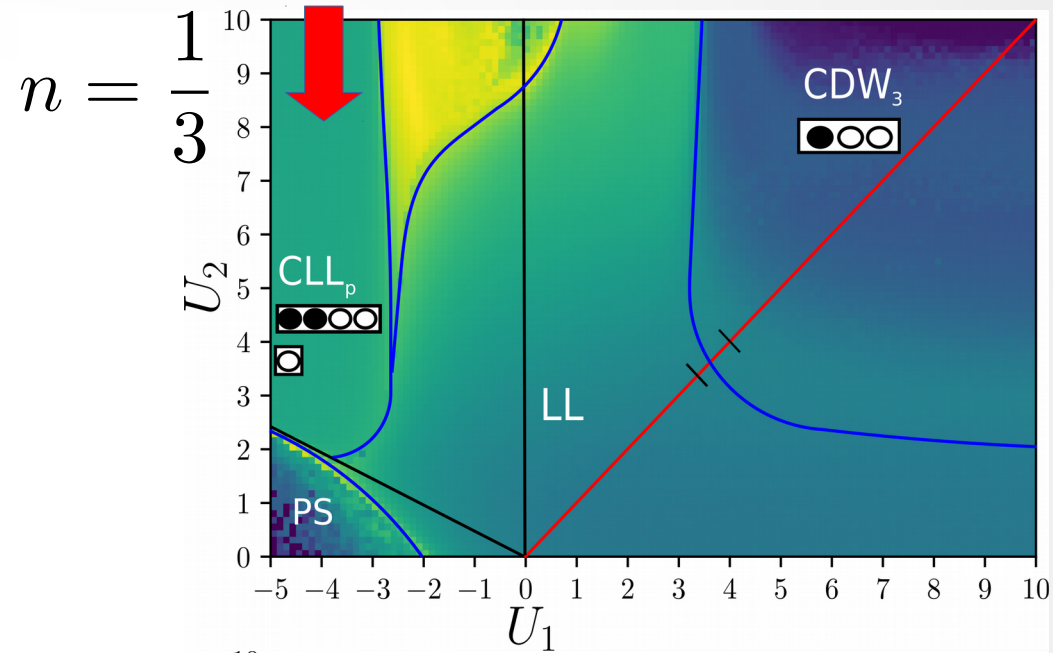
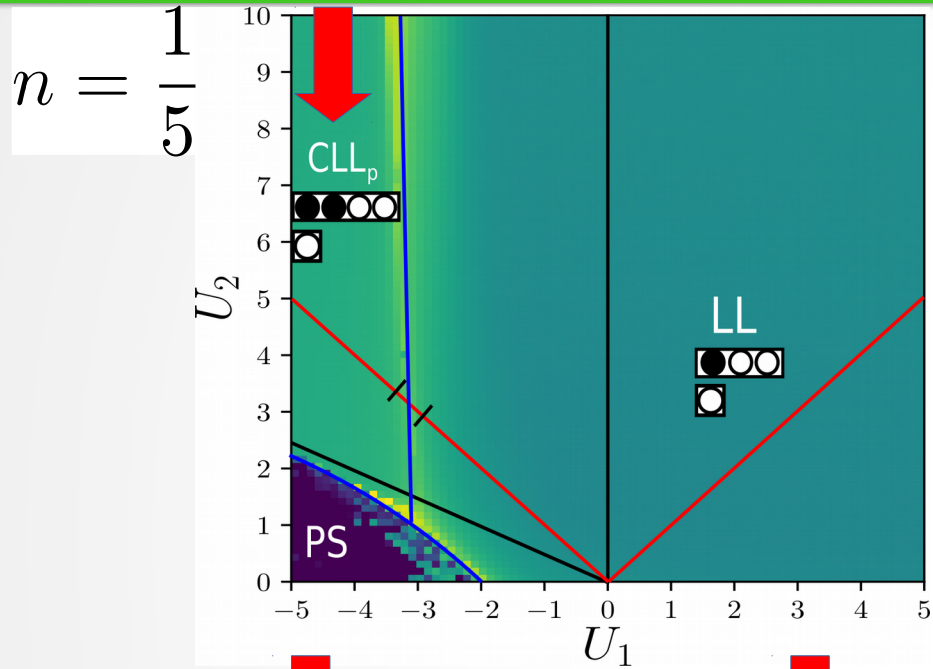
## Motivation

- growing interest in long range interactions
- **quantum simulation** with Rydberg atoms

 mapping to quantum spin models

# Overview of the results (see

<https://arxiv.org/abs/2006.07128> for more details)



# CLL phases: analytical hints

## 1) CLASSICAL LIMIT $t = 0$

- Description of ground state eigenspace:

→ exponential degeneracy

→ nontrivial microscopic d.o.f.  add quantum fluctuations

● ● 00    0  
          A    B

## 2) STRONG COUPLING $t \ll U_1, U_2$

- Perturbative effective dynamics at strong coupling:

→ map to Hilbert space of a spin- $\frac{1}{2}$  chain ( $A \rightarrow |1\rangle, B \rightarrow |-1\rangle$ )

→ apply standard perturbation theory techniques

 **XXZ model** in its gapless regime ( $|\Delta| < 1$ ):

$$H_{eff} = J \sum_{j=1}^{N_{cl}} [S_j^x S_{j+1}^x + S_j^y S_{j+1}^y + \Delta S_j^z S_{j+1}^z]$$

**Luttinger liquid  
universality class**

# CLL phases: numerical results

## Phenomenological signatures

- **Anomalous peak locations** in:
  - structure factor  $S(k)$
  - density profile Fourier transform  $n(k)$
- Nature of the **low energy excitations**:
  - gapped 1-particle excitations
  - vanishing 2-particle gap

## Phase transition

- enhanced **central charge**:  $c = \frac{3}{2}$  critical point
- emergent gapless Ising mode with  $c = \frac{1}{2}$

